

# Spatial Distribution of Nutrients in the Mississippi River System (1991–1992)

**Ronald C. Antweiler and Howard E. Taylor**

*U S. Geological Survey  
Denver Federal Center  
Denver, Colorado*

## Abstract

Concentrations of dissolved nutrients (nitrate, nitrite, ammonium and orthophosphate) were measured on surface-water grab samples collected at ten mile intervals along the entire length of the navigable portion of the Mississippi River during three cruises in June–July 1991, September–October 1991 and March–April 1992. Samples were also collected at the mouths of some of the major tributaries and, at selected points, three-sample cross sections were collected across the river to measure cross-channel variability. Simultaneously with collecting each sample, the discharge of the Mississippi River was estimated, permitting the calculation of the nutrient load in the Mississippi River at each sample point. The large number of samples collected (between 179 and 207 per cruise) give a picture of the instantaneous longitudinal variation of nutrients in the Mississippi River during three different seasons.

Both nitrate and orthophosphate loads appear to increase or remain constant downriver for each cruise, indicating that mechanisms for the removal of these compounds are not as rapid as their introduction into the river. In addition, below the confluence of most of the major tributaries, the loads show a “step” increase caused by the nitrate and orthophosphate

contributions from the tributaries. From this data, one can identify the possible sources of nitrate and orthophosphate arriving at the Gulf of Mexico from the Mississippi River. During each of the three cruises (at three different seasons), the majority of the nitrate and orthophosphate appears to have originated from the Upper Mississippi River Basin, above the confluence of the Missouri River.

Ammonium and nitrite loads appear to originate as point-sources, but disappear within approximately one hundred miles of their introduction, probably as a result of conversion to nitrate and/or nitrogen gas. Any nitrite or ammonium from the Mississippi River deposited into the Gulf of Mexico therefore probably originated within one hundred miles of the Gulf.

## Introduction and Methodology

Three sampling cruises were taken on the Mississippi River, originating near New Orleans, Louisiana and finishing in Minneapolis, Minnesota during June 23 to July 2, 1991, September 25 to October 4, 1991 and March 25 to April 4, 1992. One purpose of these cruises was to study how concentrations and transport of the dissolved nutrients nitrate, nitrite, ammonium and orthophosphate ions varied longitudinally.

nally in the Mississippi River and at the mouths of some of its major tributaries. Concentrations of these dissolved nutrients were measured on surface-water grab samples collected at ten-mile intervals along the entire length of the navigable portion of the Mississippi River. These data can be used to evaluate the potential effects that nutrients have on the Mississippi River system and on the Gulf of Mexico.

Grab samples collected from the upper three meters of the river were taken every ten miles (about once an hour) from the center of the river channel. In addition, samples were collected from the mouth of some of the major tributaries; at selected locations, three samples were collected along cross-sections to measure cross-channel variability. Samples were collected from the river with a clean 2-liter Teflon bottle placed in a weighted aluminum holder and were then transferred into pre-cleaned 250-ml opaque polyethylene bottles. All samples were immediately filtered through nylon or Nuclepore polycarbonate membrane filters with a 0.4- $\mu$ m nominal pore diameter, and then either chilled (for immediate analysis) or frozen for transport to the laboratory. No chemical preservatives were used.

Analyses were performed on an Alpkem air-segmented continuous-flow colorimetric analysis system, Model RFA-300, as described in greater detail by Antweiler et al. (1994). Determinations were always performed in duplicate; if the two determinations did not agree within the variance of the method, the sample was reanalyzed, again in duplicate. Analyses were supplemented by the determination of standard reference materials and calibration standards to evaluate precision and accuracy. Details of all the above information are given by Antweiler et al. (1995a).

The discharge of the river was estimated at the

time of sample collection (Moody, 1995), permitting the calculation of the nutrient load in the Mississippi River at each sample point. The large number of samples collected (about 200 per cruise) in the short time periods (about ten days per cruise) give a picture of the near instantaneous longitudinal variation of nutrients in the Mississippi River during three different seasons.

At three sites on the Mississippi River—Clinton, Iowa, Thebes, Missouri and Baton Rouge, Louisiana—and near the mouths of three tributaries (the Ohio River at Grand Chain, Illinois, the Missouri River at St. Charles, Missouri and the Illinois River at Valley City, Illinois), nutrient samples were collected biweekly from April 1991 to September 1992. These samples were discharge-weighted laterally-composited samples collected in glass or stainless steel containers. They were filtered through a 0.45- $\mu$ m membrane filter immediately after collection, preserved with mercuric chloride and shipped chilled to the USGS National Water Quality Laboratory, Denver, CO, for analysis. These samples were analyzed using an automated colorimetric procedure (Fishman and Friedman, 1989). Details of both the sampling protocol and analyses can be found in Coupe et al. (1995).

## Results

The results of these studies are tabulated by Antweiler et al. (1995a) and Coupe et al. (1995) and described by Antweiler et al. (1995b). The distribution of nitrate and orthophosphate ion concentrations appear to be similar for all three cruises. Concentrations are low above Minneapolis, increase rapidly below the confluence with the Minnesota River (due to its relatively high concentrations compared to the Mississippi River, around mile 1800), generally

decrease through southern Minnesota and Wisconsin (miles 1500–1800), increase through Iowa (miles 1250–1500), remain nearly constant through Missouri (miles 950–1250), decrease at the confluence with the Ohio River (mile 950), and generally remain constant downstream to the Gulf of Mexico (Figure 76). In terms of transport (or loads: they are synonymous terms), these two compounds demonstrate some important features. Both nitrate and orthophosphate loads appear to either increase or remain constant downriver for each cruise, indicating that mechanisms for the removal of these compounds are not as rapid as their introduction into the river. In addition, below the confluence of most of the major tributaries, the loads show a "step" increase caused by contributions from the tributaries (Figure 77).

The data collected biweekly at six sites in the Mississippi River Basin also provide information concerning the transport of nutrients in the Mississippi River. Nitrate transports based on these data are shown in Figures 78 and 79. The pattern of nitrate transport of nitrate at Thebes, Missouri (just above the confluence with the Ohio River) is similar to the pattern at Baton Rouge, Louisiana, during the entire sampling period although the quantity of nitrate at Thebes is less than at Baton Rouge (Figure 78). In contrast, the quantity of nitrate at the mouth of the Ohio River (Figure 79) is considerably less than in the Mississippi River at Thebes, and comparable with that from the Missouri and Illinois Rivers.

From the biweekly and upriver cruise data, one can postulate the possible sources of nitrate and orthophosphate arriving at the Gulf of Mexico from the Mississippi River. By integrating the biweekly data over the course of the year, April 1991 to April 1992, and assuming that 30 percent of the Mississippi River is diverted into the Atchafalaya River above Baton Rouge, Louisi-

ana, it is apparent that the majority of the water originates from the Ohio River (38 percent) and the Lower Mississippi River—the Mississippi River below the confluence with the Ohio River (28 percent) (Figure 80). However, the majority of the nitrate appears to have originated from the Upper Mississippi River Basin, above the confluence with the Ohio River. The Upper Mississippi, the Illinois and the Missouri Rivers account for 68 percent of the nitrate. For orthophosphate, the largest sources again appear to be the Upper Mississippi, Illinois and Missouri Rivers (52 percent), although a large percentage also comes from the Lower Mississippi River below the confluence with the Ohio River (29 percent) (Figure 80).

Ammonium and nitrite ion loads appear to originate as point-sources, but disappear within approximately one hundred miles of their site of introduction (Figure 81 shows typical data for ammonium), probably as a result of either conversion to nitrate ion and/or nitrogen gas or as a result of sorption to suspended sediment. Any nitrite or ammonium ions from the Mississippi River deposited into the Gulf of Mexico, therefore, probably originated within one hundred miles of the Gulf. However, the amount of nitrite and ammonium ions in the Mississippi River are always minor (less than 5 percent) compared with the amount of nitrate ions and therefore contribute little to the overall quantity of nutrients arriving at the Gulf of Mexico from the Mississippi River.

## References

- Antweiler, R.C., Patton, C.J. and Taylor, H.E. (1994) Automated, colorimetric methods for the determination of nitrate plus nitrite, nitrite, ammonium and orthophosphate ions in natural water samples: U.S. Geological Survey Open-File Report 93-638, 34 p.

Antweiler, R.C., Patton, C.J. and Taylor, H.E. (1995a) Chapter 3: Nutrients in Chemical data for water samples collected during four upriver cruises on the Mississippi River between New Orleans, Louisiana and Minneapolis, Minnesota, May 1990-April 1992, J.A. Moody, ed.: U.S. Geological Survey Open-File Report 94-523, p.89-125.

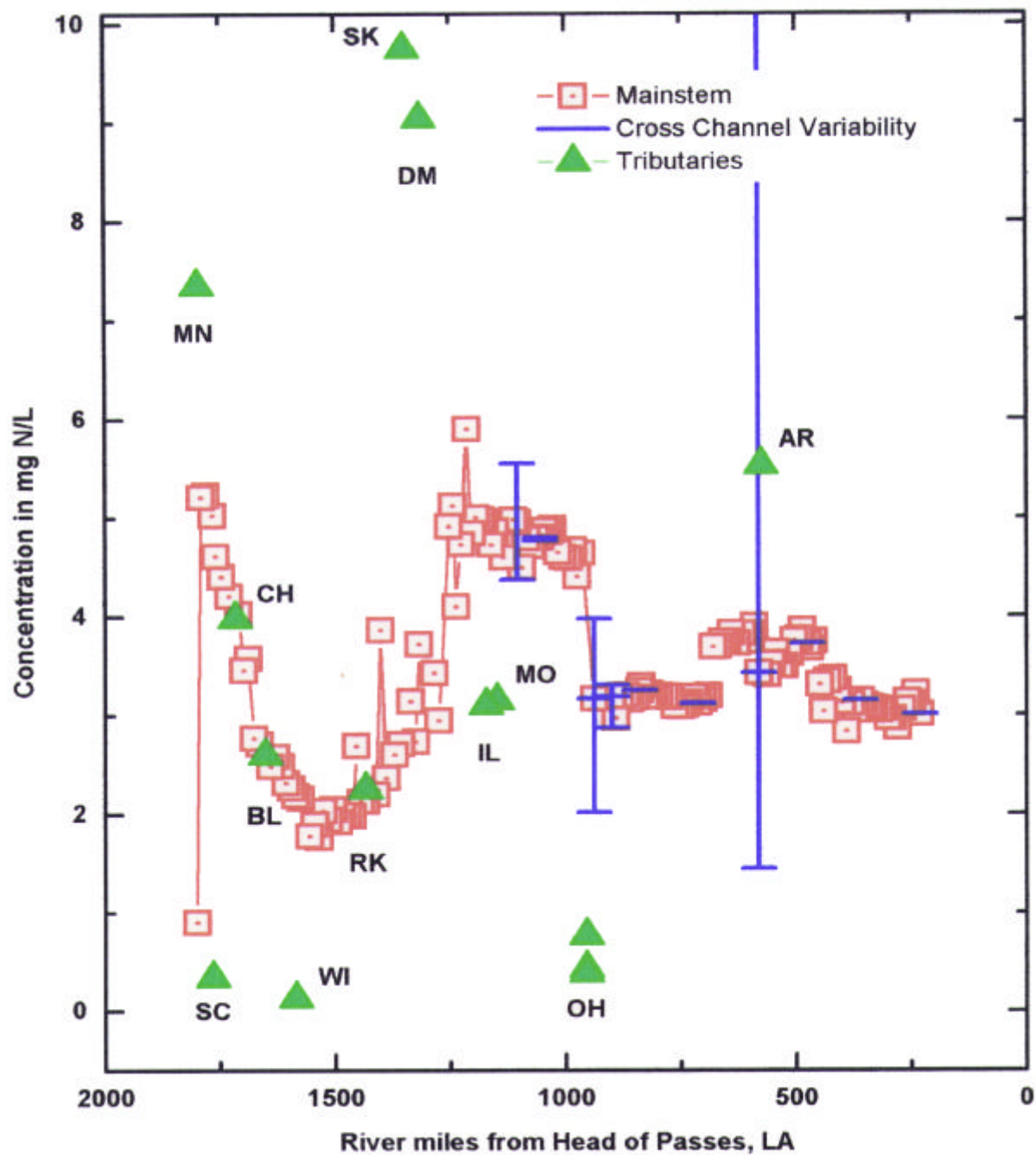
Antweiler, R.C., Goolsby, D.A. and Taylor, H.E. (1995b) Nutrients in the Mississippi River. I: Contaminants in the Mississippi River, 1987-1992, R.H. Meade, ed.: U.S. Geological Survey Circular 1133, p. 72-85.

Coupe, R.H., Goolsby, D.A., Iverson, J.L., Markovchick, D.J. and Zaugg, S.D. (1995) Pesticide, nutrient, water-discharge and physical-property data for the Mississippi River and some of its tributaries, April 1991-September 1992: U.S. Geological Survey Open File Report 93-657, 116 p.

Fishman, M.J. and Friedman, L.C. (1989) Methods for the determination of inorganic substances in water and fluvial sediments:: U.S. Geological Survey Techniques of Water Resources Investigations, book 5, chap. A1, p. 1-13.

Moody, J.A. (1995) Chapter 1: Introduction in Chemical data for water samples collected during four upriver cruises on the Mississippi River between New Orleans, Louisiana and Minneapolis, Minnesota, May 1990-April 1992, J.A. Moody, ed.: U.S. Geological Survey Open-File Report 94-523, p. 1-18.

Use of tradenames is for identification purposes only and does not imply endorsement by the U.S. Geological Survey.



**Figure 76.**

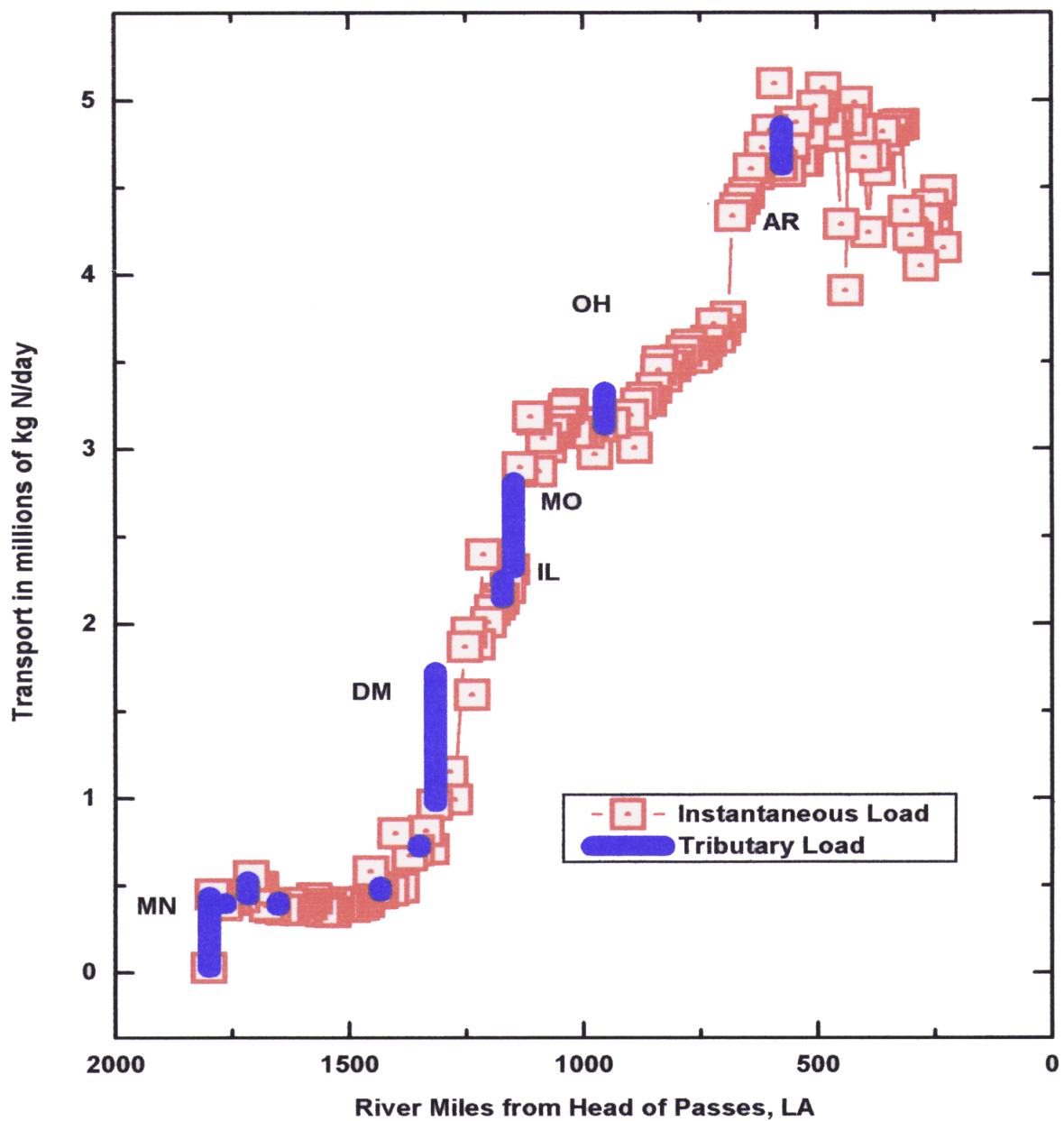
Concentration of nitrate in milligrams of nitrogen per liter in the Mississippi River during June 23–July 2, 1991.

MN = Minnesota River

SC = St. Croix River  
CH = Chippewa River  
BL = Black River

WI = Wisconsin River  
RK = Rock River  
SK = Skunk River  
DM = Des Moines River

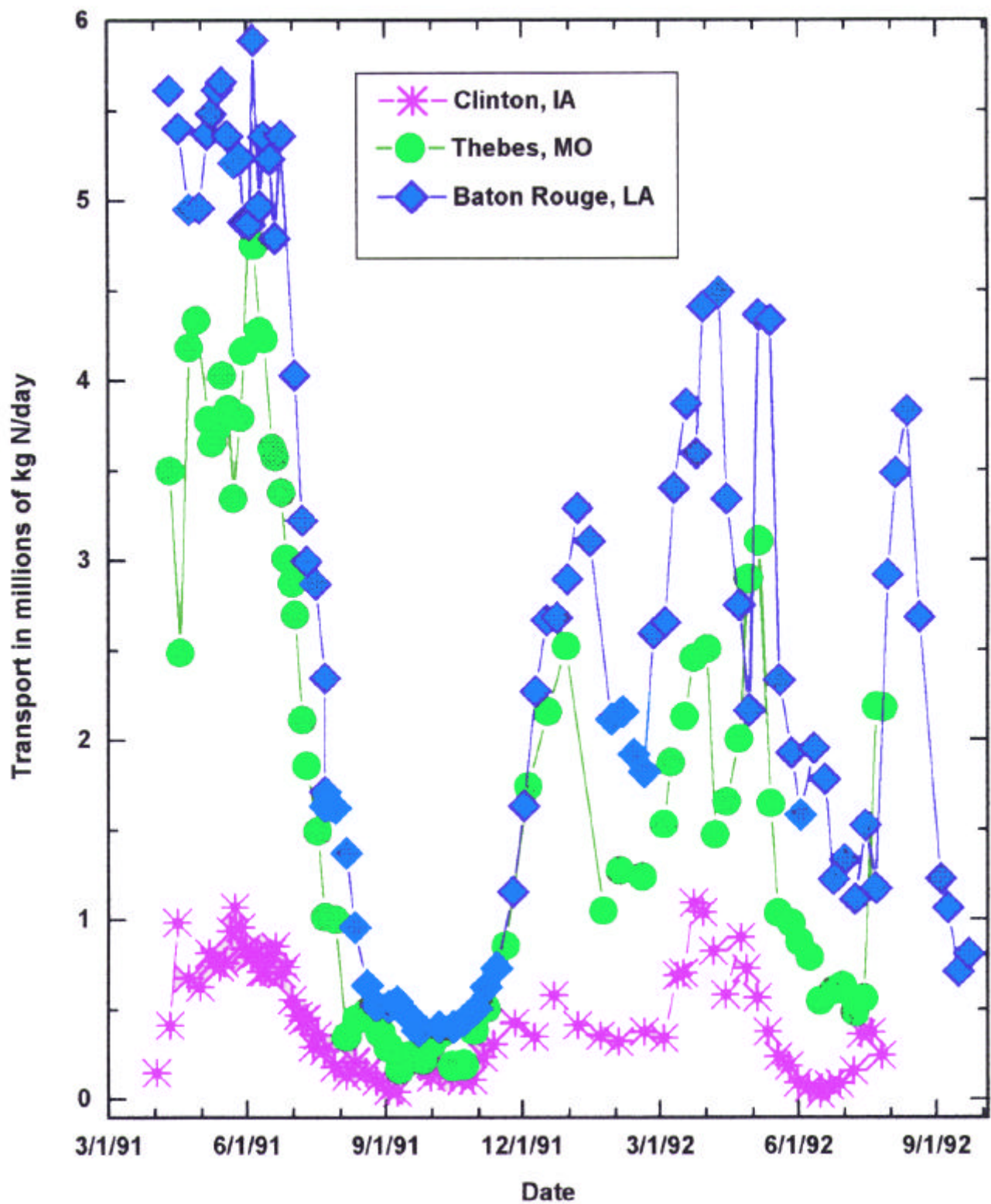
IL = Illinois River  
MO = Missouri River  
OH = Ohio River  
AR = Arkansas River



**Figure 77.**  
 Transport of nitrate in millions of kilograms of nitrogen per day in the  
 Mississippi River during June 23–July 2, 1991.

MN = Minnesota  
 River  
 DM = Des Moines  
 River  
 IL = Illinois River

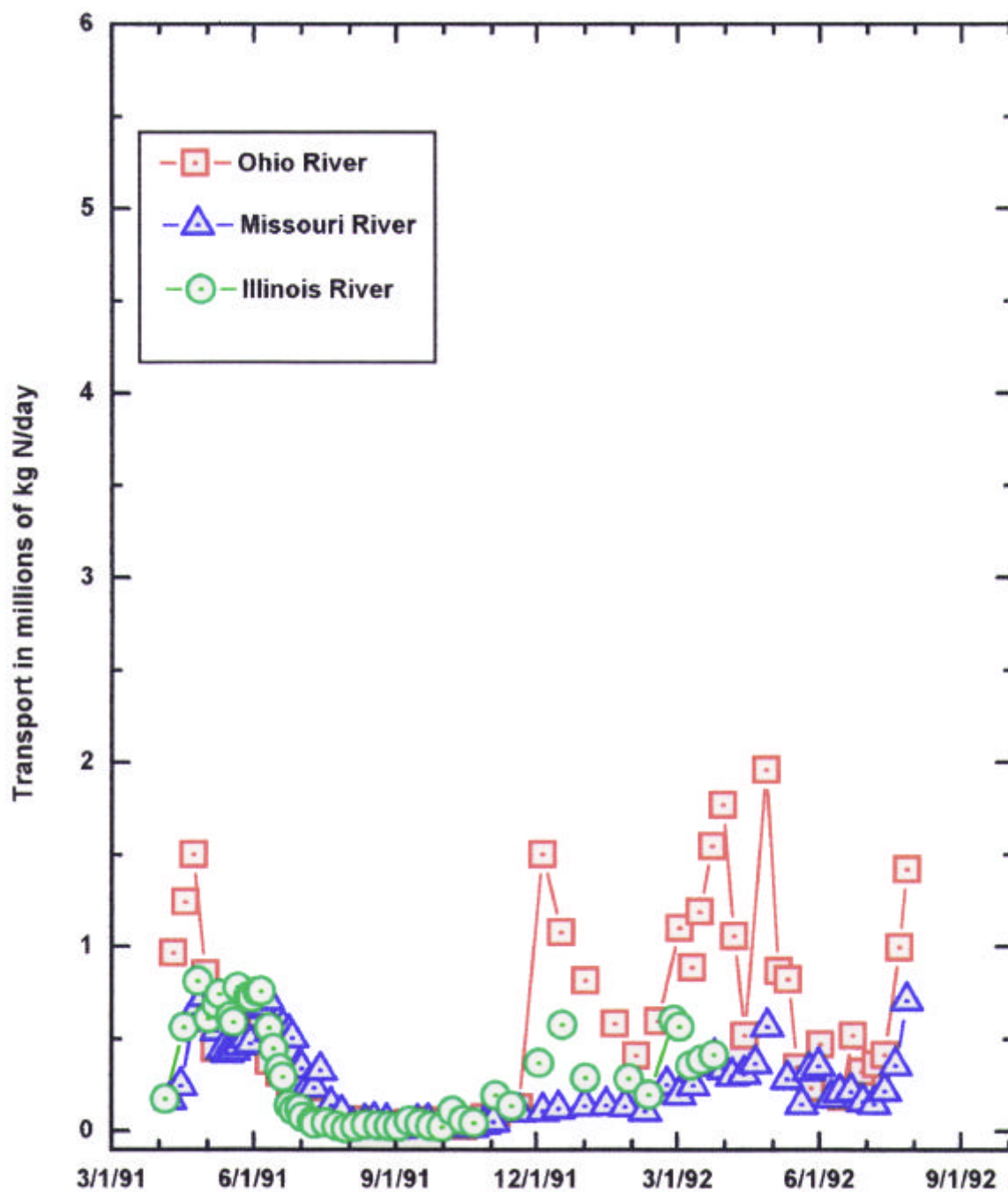
MO = Missouri River  
 OH = Ohio River  
 AR = Arkansas River



**Figure 78.**

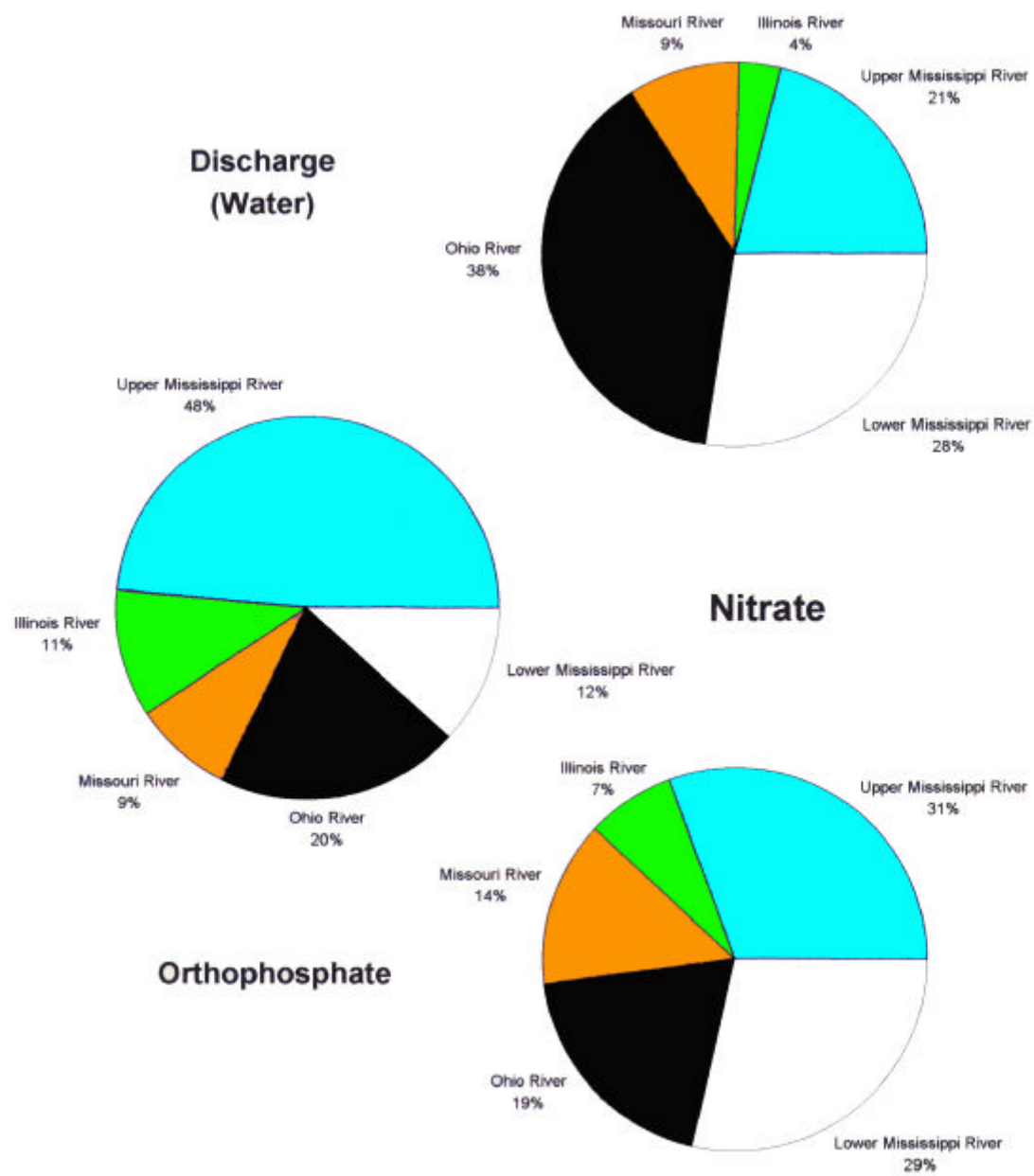
*Transport of nitrate in millions of kilograms of nitrogen per day in the Mississippi River at Clinton, Iowa; Thebes, Missouri; and Baton Rouge, Louisiana during 1991–1992.*



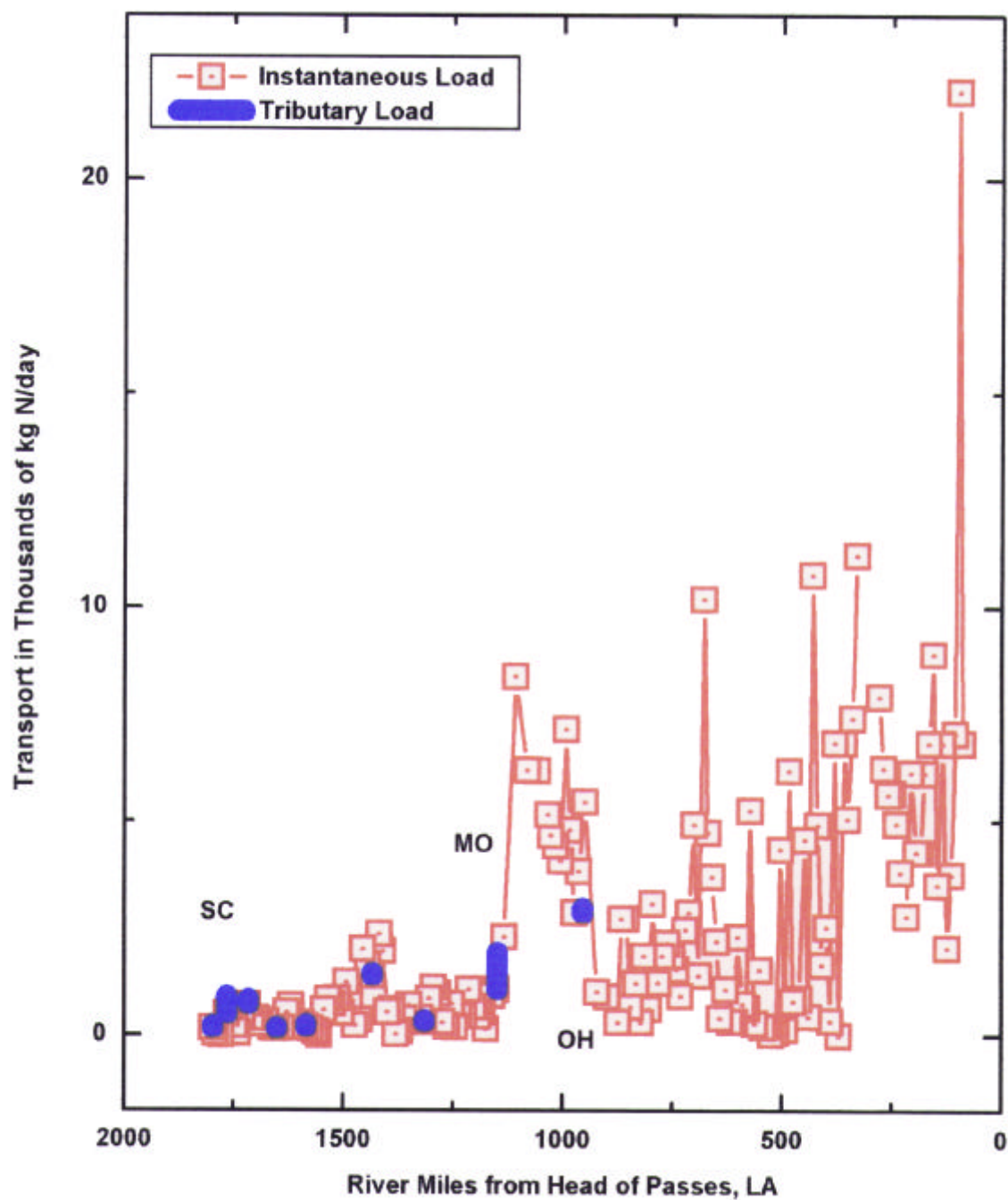


**Figure 79.**  
*Transport of nitrate in millions of kilograms of nitrogen per day in three tributaries of the Mississippi River during 1991–1992.*





**Figure 80.**  
*Sources of water, nitrate and orthophosphate in the Mississippi River during April 1991–April 1992.*



**Figure 81.**

*Transport of ammonium in thousands of kilograms of nitrogen per day in the Mississippi River during September 25–October 4, 1991.*

SC = St Croix River

MO = Missouri River

OH = Ohio River

## ***Presentation Discussion***

Ron Antweiller (U.S. Geological Survey—  
Boulder, CO)

**Fred Kopfler** (*Gulf of Mexico Program— Stennis Space Center, MS*) commented that the scale of the loadings presented for ammonium nitrogen was thousands of kilograms per day, while loadings for nitrate were millions of kilograms per day; even if the ammonium was converted to nitrate, it is about three orders of magnitude less. Therefore, it is lost in the background of the nitrate.

**Ron Antweiller** confirmed that Fred Kopfler's understanding was correct. The highest ammonium loadings in relation to nitrate he has seen was five percent. Even if all the ammonium is converted to nitrate, it still is not significant.